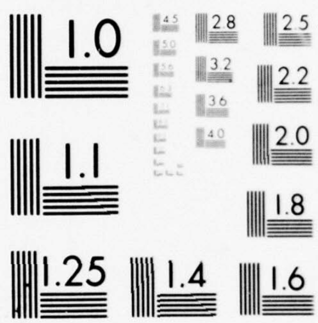
AD-A046 540 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/13
TERRAIN CHARACTERISTICS AT GATOR MINE IMPACT AND PENETRATION TE--ETC(U)
SEP 77 C E GREEN

UNCLASSIFIED WES-MP-M-77-13 NL

| OF |

AD
A046540

END
DATE
FILMED
12-77
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A046540

MISCELLANEOUS PAPER M-77-13

TERRAIN CHARACTERISTICS AT GATOR MINE IMPACT AND PENETRATION TEST SITES ABERDEEN PROVING GROUND, MARYLAND

by

Charles E. Green

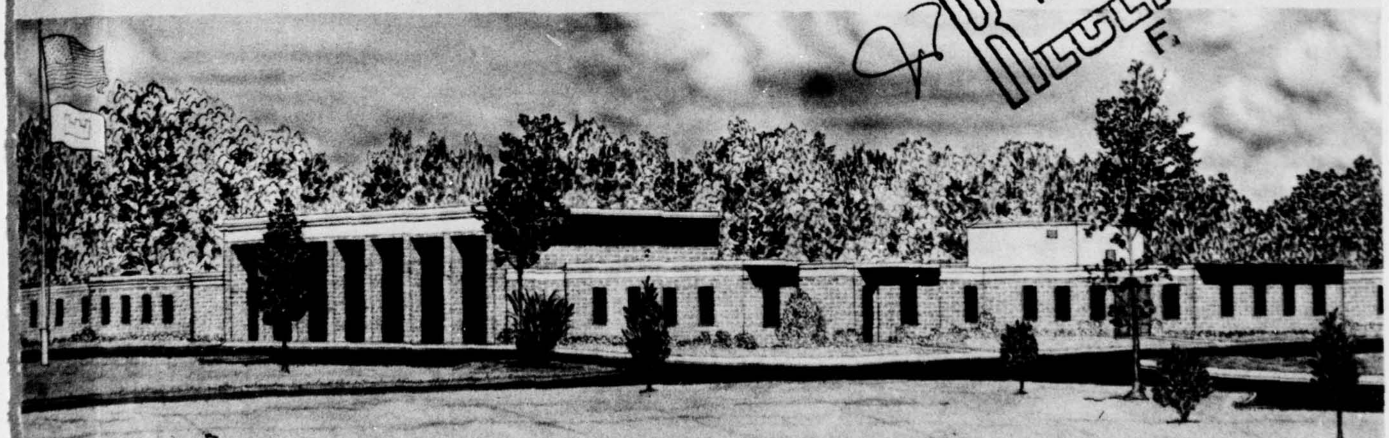
Mobility and Environmental Systems Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

September 1977

Final Report

Approved For Public Release; Distribution Unlimited

DDC
RECEIVED
NOV 17 1977
F



Prepared for Picatinny Arsenal
Dover, New Jersey 07801

AD No.
DDC FILE COPY

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Miscellaneous Paper M-77-13 — 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) TERRAIN CHARACTERISTICS AT GATOR MINE IMPACT AND PENETRATION TEST SITES, ABERDEEN PROVING GROUND, MARYLAND.	5. TYPE OF REPORT & PERIOD COVERED: (9) Final Report.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Charles E./Green	8. CONTRACT OR GRANT NUMBER(s): (14) WES-MP-M-77-13
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Mobility and Environmental Systems Laboratory, P. O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (12) 44p.
11. CONTROLLING OFFICE NAME AND ADDRESS: Picatinny Arsenal, Dover, New Jersey 07801	12. REPORT DATE: (11) Sep[redacted]77
	13. NUMBER OF PAGES: 41
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

D D C
NOV 17 1977
F

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Impact	Soil penetration
Mines (Ordnance)	Soil strength
Off-road mobility	Terrain

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of impact and penetration tests were conducted to evaluate the performance of the Gator Mine. The tests were conducted by Picatinny Arsenal at I Field, Aberdeen Proving Ground (APG), Maryland, during the period 11-15 April 1977 to provide data to compare the penetration performance of three types of Gator mines (Air Force, S-shaped, and 110). These data were necessary to document terrain characteristics at the APG sites used in the impact and penetration tests of the Gator Mine. The terrain characteristics were needed to develop mine penetrability relations and →(Continued)

038 100

mt

20. ABSTRACT (Continued)

cont

to provide a baseline for theoretical extrapolation of the Gator Mine performance to other world environments. The results of this study are summarized as follows:

a. The variation in soil consistency with depth and location within the site provided a wide range of soil conditions for evaluating mine performance but did not include locations exhibiting soil strengths that would result in marginal vehicle performance.

b. The average 0- to 12-in. cone index (CI) ranged from 82- to 626+ with most of the readings occurring in the 200-400 range.

c. The average 0- to 12-in. dynamic cone penetrometer index (DCPI) ranged from 5 to 57 with most of the readings in the 10-30 range.

d. A wide range of values for horizontal displacement from impact point, penetration, impact angle, at-rest angle, and depth of overburden occurred during testing.

e. Based on soil strength conditions, the I Field site is analagous to 83 percent of the Fulda Gap area in West Germany.

f. Standard vehicles could operate with ease in the test area.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTUTITE AN OFFICIAL ENDORSEMENT OF APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

BY
DISTRIBUTION/AVAILABILITY CODES
SPECIAL
A

Preface

The U. S. Army Engineer Waterways Experiment Station (WES) participation in this phase of the Gator Mine System coordinated test program as requested by Picatinny Arsenal in a telephone conversation on 18 October 1976. Funds were provided by U. S. Army Armament Research and Development Command (ARRADCOM) on MIPR No. 7311-0031 dated 18 April 1977. The study was conducted during the period 11-15 April 1977.

The study was conducted under the general supervision of Mr. W. G. Shockley, Chief, Mobility and Environmental Systems Laboratory (MESL), and under the direct supervision of Mr. A. A. Rula, Chief, Mobility Systems Division (MSD), MESL. The U. S. Army Aberdeen Proving Ground, Maryland, supported WES in the collection of field data. The field program was conducted by Messrs. C. E. Green, L. M. Lewis, and D. E. Strong, MSD. This report was prepared by Mr. Green.

Commander and Director of WES during this study and the preparation of this report was COL J. L. Cannon, CE. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, Metric (SI) to U. S. Customary and U. S. Customary to Metric (SI) Units of Measurement

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
Metric (SI) to U. S. Customary		
millimetres	0.03937007	inches
centimetres	0.3937007	inches
grams per cubic centimetre	0.0361273	pounds (mass) per cubic inch
U. S. Customary to Metric (SI)		
inches	2.54	centimetres
feet	0.3048	metres
square inches	6.4516	square centimetres
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch	6.894757	kilopascals
degrees (angle)	0.01745329	radians

TERRAIN CHARACTERISTICS AT GATOR MINE IMPACT AND PENETRATION TEST SITES, ABERDEEN PROVING GROUND, MARYLAND

Background

1. A series of impact and penetration tests were conducted to evaluate the performance of the Gator mine. The tests were conducted by Picatinny Arsenal at I Field, Aberdeen Proving Ground (APG), Maryland, during the period 11-15 April 1977 to provide data to compare the penetration performance of three types of Gator mines: Air Force, S-shaped, and 110 (Figure 1). The U. S. Army Engineer Waterways Experiment Station (WES) had collected field data in support of similar impact and penetration tests for another munitions system, the Remote Anti-Armor Mine Systems (RAAMS) mine, in July 1976 at APG.[1] Data from these tests were useful in providing a general description of the test areas to relate penetration performance to soil strength. However, because soil strength changes as a function of moisture content, these data did not provide sufficient information to document conditions for the Gator mine tests. Therefore, Picatinny Arsenal requested that WES take additional terrain data in support of the Gator mine tests.

Purpose and Scope

2. The purpose of this study was to document terrain characteristics at the sites at APG used in the impact and penetration tests of the Gator mine. The terrain characteristics were needed to develop mine penetrability relations and to provide a baseline for theoretical extrapolation of the Gator mine performance to other environments.

3. The following types of data were collected to describe site terrain properties for these purposes, as described in Reference 2.

_a_. Soil strength in terms of cone index (CI) and/or rating cone index (RCI) at selected locations for the 0- to 12-in.* layer.

_b_. Soil strength in terms of dynamic cone penetration index (DCPI).

_c_. Description of vegetation or ground cover.

_d_. Soil moisture content at selected locations.

_e_. Soil descriptions according to the Unified Soil Classification System (USCS) and U. S. Department of Agriculture (USDA) plus specific gravity and organic content.

_f_. Soil density.

In addition, a general description was made of each site, and photographs were taken where appropriate. The depth of penetration and orientation of the mine were documented for approximately 80 mine tests. Soil trafficability for standard military vehicles within the test area was estimated. A comparison of I Field to the Fulda Gap area in West Germany was made.

Definitions

4. Special terms used in this report, taken from Reference 1, are defined below:

_a_. Soil terms

(1) Fine-grained soil. A soil of which more than 50 percent of the grains, by weight, will pass a No. 200 sieve (smaller than 0.074 mm in diameter).

(2) Fines. Grain sizes that will pass the No. 200 sieve (smaller than 0.074 mm in diameter).

(3) Coarse-grained soil. A soil of which more than 50 percent of the grains, by weight, will be retained on a No. 200 sieve (larger than 0.074 mm in diameter).

(4) Sand. A coarse-grained soil with the greater percentage of the coarse fraction (larger than 0.074 mm) passing the No. 4 sieve (4.76 mm).

(5) Sand with fines, poorly drained. A sand that contains some fines and is slow-draining when wet. Such sands

---

* A table of factors for converting metric (SI) units to U. S. customary units and U. S. customary units to metric (SI) units of measurement is presented on page 4.

behave similarly to wet, fine-grained soils under vehicular traffic.

(6) Liquid limit. The liquid limit is generally conceded to represent the moisture content at which the characteristics of a mixture of soil and water change from plastic to liquid.

(7) Plastic limit. The plastic limit is generally conceded to represent the moisture content at which a mixture of soil and water begins to take on plastic properties (i.e. undergoes appreciable deformation with little change in volume).

(8) Plasticity index. The numerical difference between the liquid and plastic limits. The numerical value of the plasticity index is generally a good indication of the plasticity or clayeyness of a soil: highly plastic clays generally have high plasticity indexes; less plastic clays have lower plasticity indexes.

(9) Moisture content. The ratio, expressed as a percentage, of the weight of water in the soil to the weight of the solid particles.

(10) Density. The unit weight in pounds per cubic foot. Unless specifically stated otherwise, the density is the dry unit weight.

b. Strength terms

(1) Cone index (CI). An index of the shearing resistance of soil obtained with the cone penetrometer. The CI is considered to be a dimensionless number representing the resistance of a medium to penetration of a 30-deg, right-circular cone of 0.05-sq-in. base area. The number, although considered dimensionless, is actually the number of pounds of force exerted on the handle divided by the area of the cone base in square inches.

(2) Remolding index (RI). A ratio that expresses the change in strength of a fine-grained soil or a sand with fines, poorly drained, that may occur under traffic of a vehicle.

(3) Rating cone index (RCI). The product of the measured CI and RI for the same layer of soil. This index is valid only for fine-grained soils and for sands with fines, poorly drained.

(4) Dynamic cone penetration index (DCPI). An index of the shearing resistance of soil obtained with a drop cone penetrometer. The index is the number of blows of a 12.3-lb hammer dropped 8 in. required to drive a

30-deg, right-circular cone of 0.5-sq-in. base area a given distance into a medium.

c. Vehicle cone index (VCI). An index assigned to a given vehicle, based on certain vehicle characteristics, that indicates that minimum soil strength in terms of RCI (for fine-grained soils) or CI (for coarse-grained soils) required for a prescribed number of passes. VCI for coarse-grained soils is distinguished from VCI for fine-grained soils by the addition of an S for coarse-grained soils. Furthermore, numbers are used to distinguish the VCI's for one tire inflation pressure from another; e.g., VCIS-35 and VCIS-72.5 are the VCI's for 35- and 72.5-psi tire inflation pressures, respectively, on sand. VCIS applied to one pass only. VCI for fine-grained soils is identified for a given number of passes by a subscript, usually VCI_1 or VCI_{50} for 1 or 50 passes, respectively.

Site Description

5. Picatinny Arsenal selected I Field at APG for characterization and mine tests. The location, topography, vegetation, and soil moisture conditions are described in the following paragraphs.

6. I Field is on Gunpowder Neck Peninsula. The field is bounded on the west by Ricketts Point Road, on the east by Chesapeake Bay, and on the north and south by woodlands. A rectangle approximately 1600 by 2200 ft, with the length oriented in an east-west direction, was chosen for characterization. The topography of I Field ranges from an upland flat near the western boundary to a bottomland depression beginning in the north-central section and extending in a south-southeast direction through the site near its eastern boundary. Site relief ranges up to 50 ft, and slopes range up to about 5 percent. At the time the site was sampled (11-15 April 1977), the area was bare and there was considerable evidence of erosion on the slopes throughout the test area (Figure 2). Prior to testing, no specific site preparation was required; however, during RAAMS tests in July 1976 at I Field,[1] various sections were disked or rototilled (up to a depth of 10 in. in places) to simulate agricultural lands.

7. The soil[3] at this site, which was derived from Coastal Plain deposits, is deep and is medium to light in texture. In the upper

topographic layer, the soil is brownish yellow and well drained. In places, the subsoil is mottled gray, and large patches of gray subsoil were exposed along the eastern-facing slope. According to USDA, the upland soil is classified as Sassafras loam, and the bottomland as Keyport silt loam. The subsoil of the Keyport series is mottled gray, which is evidence of imperfect internal drainage. The soil in the 0- to 12-in. depth varied from loam to silty clay loam. Classification according to the USCS varied from sandy clay (CL) to sandy silt (ML).

Data Collected and Procedures Used

8. The data collected at I Field included the strength, density, moisture content, classification, specific gravity, and organic content of the surface soil for site characterization and additional postimpact data on the Gator mine (Tables 1-3). The data collected and the procedures used are described in the following paragraphs. The procedures used to characterize the sites for this study were generally in accordance with those established by WES for soil trafficability studies and those outlined in References 1 and 2.

Soils data

9. Prior to the actual data collection in the field, an inspection was made of the soil conditions on I Field. Obvious changes in soil moisture content were noted so that measurements could be made later at these sites. The initial inspection did not reveal any significant changes in soil type at I Field; however, to document this uniformity, several of the sites used for moisture content determination were also sampled for soil type data. Bulk soil samples were taken at selected sites from the 0- to 6- and 6- to 12-in. layers for laboratory determination of organic matter content, grain-size distribution, Atterberg limits, and specific gravity; organic matter content was determined by means of a modified Walkey rapid dichromate oxidation and the values expressed as percentages by weight. Soil was classified according to the USCS and USDA systems. A 2-in.-diam trafficability sampler was used to obtain moisture content-density samples in the 0- to 6- and 6- to

12-in. soil layers. When the soil was too firm to allow penetration in 3-in. vertical increments with the trafficability sampler, a disturbed soil sample was taken from the prescribed depths for determination of moisture content. Laboratory-determined data are listed in Table 1.

10. Soil strength as a function of depth was measured in terms of CI and DCPI. These data (Table 2) were taken near the intersections of the various grid lines shown in Figure 3. Figure 3 shows the distribution of soil strength throughout the test area. This map was developed by assuming that the average soil strength for the 0- to 12-in. layer varied linearly between grid intersection points. Although this assumption is often incorrect, the map does indicate average soil strengths to be expected throughout the test site. At each location sampled, three sets of CI measurements were made at the surface and at 1-in. vertical increments to a depth of 6 in., then at 3-in. increments to 12 in. A plus sign was used to indicate that the soil strength exceeded the capacity of the cone penetrometer. (If the average CI was determined using one or more readings that exceeded the capacity of the penetrometer, a plus sign was placed after the average value in Table 2.) At each sample location, one set of DCPI measurements was made at 6-in. vertical increments to a depth of 12 in.

Site data at mine impact locations

11. Because the site characterization indicated a variation in soil consistency with depth and location within the site, it was necessary to obtain soil strength data adjacent to mine impact locations. These data are listed in Table 3. At each impact location, three sets of CI measurements were made at each point of an equilateral triangle whose sides were about 3 ft long. One set of DCPI measurements was made near the center of the triangular sampling pattern.

Mine impact data

12. Measurements were made at each mine location to determine (a) initial and final penetration depths, (b) horizontal displacement from impact point, (c) impact angle and attitude, (d) final attitude, (e) at-rest angle, and (f) overburden (Figure 4). Standard survey techniques and instruments were used to take these measurements.

Discussion of Results

13. The data collected at APG were not analyzed rigorously; however, some observations were made. These are discussed in the following paragraphs.

Soils data

14. Site characterization. The site was free of surface vegetation and the soil was generally classified as a lean clay (CL). The average 0- to 12-in. CI (Table 2) ranged from 82- to 626+ with most of the readings occurring in the 200-400 range. CI was assumed to be equal to RCI because the soil gained strength with compaction. The average 0- to 12-in. DCPI (Table 2) ranged from 5 to 57, with most of the readings in the 10-30 range. Figure 3 shows that several high-strength areas (based on CI) occurred near the B-1, C-3, E-2, and E-5 intersections, and low-strength areas occurred near the B-6, B-10, B-11, and B-12 intersections.

15. Mine impact locations. The average 0- to 12-in. CI (Table 3) ranged from 58 to 672 with most of the readings occurring in the 200-400 range. The number of blows required to penetrate the surface foot ranged from 3 to 49; most of the readings were in the 10-30 range.

Mine performance

16. The measured mine data for the twenty-seven Air Force, twenty-nine S-shaped, and twenty-four 110 mines are presented in Table 4 (8 of the 88 mines dropped were lost and could not be documented). As can be seen in Table 4, a majority of the mines displaced horizontally after impact. The distance displaced varied from 8 in. to a maximum of 324 in. (mine 38). The initial and final penetration of the mines varied from 0 in. to a maximum of 9.5 in. The impact angle and at-rest angle varied from 0 to 90 deg. Overburden (i.e. the amount of material atop the mine after impact) in most cases was 0 in.; however, in three tests overburden depths were 1.75, 2.5, and 5.0 in. for mines 33, 18, and 61, respectively.

17. Plots of initial depth of penetration versus average CI and versus DCPI for the 0- to 12-in. layer are shown in Figures 5 and 6, respectively, for the Air Force mine, in Figures 7 and 8, respectively,

for the S-shaped mine, and in Figures 9 and 10, respectively, for the 110 mine. The 0- to 12-in. layer was assumed to be the critical layer for this study. These figures indicate the scatter pattern for the various soil strengths encountered and show that the mines do not penetrate uniformly. This scatter pattern could be due to the effects of various glide patterns and impact velocities at which the mines hit the ground. A much better correlation could possibly be determined if the previously mentioned variables were considered.

Comparison of I Field to other environments

18. Terrain data similar to that for I Field has been developed in a previous study at WES (HIMO Study[4]) for the Fulda Gap area in West Germany. Previous data taken at I Field (Reference 1) were extrapolated to that area. The procedure used for extrapolation is presented in detail in Reference 1. Generally, the procedure consists of (a) assigning soil strength in terms of CI and RCI to mapped terrain units (soil type-drainage situation) on the basis of predictions made with the WES soil moisture and soil strength predictions (SMSP) model;[5] (b) using a cumulative areal occupancy of RCI curve to compute weighted averages that imply areal occupancy to be expected for selected RCI values; and (c) computing the expected areal occupancy for a data base year.

19. By using the procedure presented in Reference 1, it was determined that an RCI $\geq$100 applied to 83 percent of the Fulda Gap area in West Germany. The 0- to 12-in. average CI (CI assumed equal to RCI) for the 80 impact sites (Table 3) at I Field was greater than 100 for all the sites except No. 87. This indicates that the I Field site is similar in terms of soil strength to 83 percent of the Fulda Gap area in West Germany.

Estimation of vehicle performance

20. The Gator mine system includes both an antivehicle and an antipersonnel mine. Therefore, to evaluate the mine performances in a given environment such as I Field, an estimation of vehicle performance for the same environment should be made. If the vehicles in question could not operate in the environment, the mine would not be required.

21. Therefore, to provide a guide for the Gator mine performance documented during the APG tests in terms of vehicle performance, the WES VCI method of computing minimum soil strength requirements for ground-crawling vehicles to complete a prescribed number of passes in a straight-line path was used to estimate the soil trafficability of standard military vehicles. The minimum CI requirements for various standard military vehicles are shown in Table 5. It must be noted that the values shown in Table 5 are somewhat generalized and that each vehicle has a specific CI requirement for a given number of passes. For example, the minimum soil strengths in terms of RCI required for an M60A1 tank to complete one pass (VCI_1) and 50 passes (VCI_{50}) are 20 and 48, respectively. If the soil strength (RCI) exceeds these numbers, the vehicle can accelerate, climb a slope, or tow a load.

22. An examination of Table 2 shows that the average soil strength data for the 6- to 12-in. layer within I Field (with the exception of one site) was greater than the soil strength requirements for the standard military vehicles shown in Table 5. This indicates that the standard military vehicles can make 50 passes at almost any location within the area.

Summary of Results

23. The results of this study are summarized as follows:

- a. The variation in soil consistency with depth and location within the site provided a wide range of soil conditions for evaluating mine performance but did not include locations exhibiting soil strengths that would result in marginal vehicle performance.
- b. The average 0- to 12-in. CI ranged from 82- to 626+ with most of the readings occurring in the 200-400 range.
- c. The average 0- to 12-in. DCPI ranged from 5 to 57 with most of the readings in the 10-30 range.
- d. A wide range of values for horizontal displacement from impact point, penetration, impact angle, at-rest angle, and depth of overburden occurred during testing.
- e. Based on soil strength conditions, the I Field site is analogous to 83 percent of the Fulda Gap area in West Germany.
- f. Standard military vehicles could operate with ease in the test area.

References

1. Rula, A. A. and Rohani, B., "Characterization of Selected Areas for Evaluation of Performance of the XM718/741 Remote Anti-Armor Mine Systems (RAAMS)," Miscellaneous Paper M-77-6, Apr 1977, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

2. Lundien, J. R. and Miller, C. A., "A Study of Impact and Penetration of the Gator Mine in Earth Materials," Miscellaneous Paper M-76-15, Aug 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3. Perkins, S. O. and Winant, H. B., "Soil Survey of Harford County, Md.," No. 26, 1927, Bureau of Chemistry and Soils, Department of Agriculture, Washington, D. C.

4. Nuttall, C. J. and Randolph, D. D., "Mobility Analyses of Standard- and High-Mobility Tactical Support Vehicles (HIMO Study)," Technical Report M-76-3, Feb 1976, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. Smith, M. H. and Meyer, M. P., "Automation of a Model for Predicting Soil Moisture and Soil Strength (SMSP Model)," Miscellaneous Paper M-73-1, Jan 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Table 1

Site Characterization, I Field, APG, Maryland

						Soil Classification								
						USDA				SCS				
						Grain Size by Weight, %								
Site Location*	Depth in.	Moisture Content %	Density g/cm^3	Organic Content %	Specific Gravity	Sand	Silt	Clay	Soil Type	Percent Fines <0.074	LL	PL	PI	Soil Type**
A-2	0-1	13.8	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	13.9	1.76	-	-	-	-	-	-	-	-	-	-	-
	6-12	17.0	-	-	-	-	-	-	-	-	-	-	-	-
A-12	0-1	19.3	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	21.4	1.82	-	-	-	-	-	-	-	-	-	-	-
	6-12	21.9	-	-	-	-	-	-	-	-	-	-	-	-
C-3	0-1	11.4	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	15.3	1.64	1.6	2.69	35	44	21	Loam	55	29	19	10	CL
	6-12	16.1	-	1.6	2.70	29	54	17	Silt, loam	55	29	19	10	CL
C-7	0-1	7.5	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	15.9	1.95	-	-	-	-	-	-	-	-	-	-	-
	6-12	16.7	-	-	-	-	-	-	-	-	-	-	-	-
D-5	0-1	8.2	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	10.2	1.97	1.2	2.68	36	51	13	Silt, loam	50	21	17	4	CL
	6-12	11.1	-	-	-	20	51	29	Silty clay loam	60	24	19	5	CL-ML
D-10	0-1	16.6	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	19.1	1.77	4.4	2.62	38	43	19	Loam	48	26	11	15	CL
	6-12	19.3	-	4.1	-	32	50	18	Silt, loam	55	29	23	6	CL

(Continued)

NOTE: Tests were run on 12 April 1977. LL = liquid limit; PL = plastic limit; PI = plasticity index.
* Alphanumeric system used to identify grid squares is shown in Figure 3.
** CL = lean clay; ML = silt.

Table 1 (Concluded)

Site Location	Depth in.	Moisture Content %	Density g/cm^3	Organic Content %	Specific Gravity	Soil Classification: USDA Grain Size by Weight, % Sand	Silt	Clay	Soil Type	USCS Percent Fines <0.074	LL	PL	PI	Soil Type
E-8	0-1	11.2	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	13.3	1.93	-	-	-	-	-	-	-	-	-	-	-
	6-12	13.1	-	-	-	-	-	-	-	-	-	-	-	-
E-7	0-1	14.9	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	14.4	1.94	2.5	2.67	24	59	17	Silt, loam	66	34	23	11	CL
	6-12	14.5	-	2.1	2.67	22	62	16	Silt, loam	68	27	14	13	CL
F-3	0-1	15.8	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	17.2	1.80	-	-	-	-	-	-	-	-	-	-	-
	6-12	17.5	-	-	-	-	-	-	-	-	-	-	-	-
G-7	0-1	24.6	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	20.8	1.75	-	-	-	-	-	-	-	-	-	-	-
	6-12	22.1	-	-	-	-	-	-	-	-	-	-	-	-
G-11	0-1	13.2	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	14.2	1.84	-	-	-	-	-	-	-	-	-	-	-
	6-12	14.7	-	-	-	-	-	-	-	-	-	-	-	-
H-4	0-1	13.3	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	15.8	1.87	2.6	2.65	24	61	15	Silt, loam	65	22	14	8	CL
	6-12	15.1	-	2.1	2.66	11	62	27	Silt, loam	68	31	21	10	CL
H-7	0-1	10.8	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	18.3	1.94	-	-	-	-	-	-	-	-	-	-	-
	6-12	18.9	-	-	-	-	-	-	-	-	-	-	-	-
I-7	0-1	16.5	-	-	-	-	-	-	-	-	-	-	-	-
	0-6	17.4	1.75	-	-	-	-	-	-	-	-	-	-	-
	6-12	17.7	-	-	-	-	-	-	-	-	-	-	-	-

Table 2

Soil Strength Data at Site Locations, I Field, APG, Maryland

Site	Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
Location*	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
A-1	80	130	140	170	250	250	260	300	220	183	260	222	6	9	15
A-2	60	100	130	150	240	300	310	300	310	184	307	246	5	8	13
A-3	120	100	200	190	240	270	250	300	300	196	293	240	9	9	18
A-4	60	70	100	180	220	250	400	500	510	183	487	335	7	13	20
A-5	30	40	50	70	80	90	100	250	360	66	237	152	2	5	7
A-6	70	90	70	70	70	70	80	100	210	74	130	102	3	4	7
A-7	60	50	60	60	100	120	110	400	650	80	387	234	2	17	19
A-8	180	200	220	220	170	190	150	150	170	190	157	174	6	7	13
A-9	40	50	10	30	30	60	80	110	170	43	120	82	1	4	5
A-10	60	70	80	70	80	90	80	150	230	76	153	114	4	5	9
A-11	50	70	40	80	70	100	60	120	140	67	107	87	3	6	9
A-12	45	60	50	60	50	80	90	110	170	62	123	92	3	4	7
B-1	70	180	350	650	750+	750+	750+	750+	750+	500	750+	625+	19	38	57
B-2	70	120	150	200	210	350	370	350	350	210	357	384	7	10	17
B-3	120	230	240	240	240	300	320	250	500	241	357	299	8	9	17
B-4	40	60	70	100	120	120	250	270	300	109	273	191	3	6	9
B-5	20	30	40	50	60	80	90	130	400	53	207	130	3	16	19
B-6	20	30	40	70	50	70	80	120	130	53	110	82	2	3	5
B-7	40	60	70	75	90	140	230	320	420	101	323	212	3	8	11
B-8	60	110	140	170	250	380	490	550	450	229	497	363	6	13	19
B-9	50	100	100	120	120	140	230	230	230	123	230	176	4	8	12
B-10	70	60	70	80	110	140	150	200	350	97	233	165	3	7	10
B-11	60	40	100	90	120	130	130	210	280	96	207	152	2	7	9
B-12	50	80	90	100	130	110	140	200	290	100	210	155	4	5	9

(Continued)

NOTE: Plus sign indicates that the capacity of the cone penetrometer was exceeded. (Sheet 1 of 5)

* See Figure 3 for site locations.

Table 2 (Continued)

Site Location	Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
C-1	70	110	200	210	220	320	400	600	720	219	573	396	16	21	37
C-2	50	80	70	90	100	200	350	480	400	134	410	272	8	17	23
C-3	100	190	290	440	750+	750+	750+	750+	750+	467	750+	608	19	24	43
C-4	60	120	230	280	270	320	350	400	470	233	407	320	15	16	31
C-5	50	100	130	150	170	180	180	430	400	137	337	237	7	12	19
C-6	30	40	60	100	120	100	100	170	300	79	190	134	4	8	12
C-7	40	60	70	90	170	230	250	380	440	130	357	244	3	15	18
C-8	20	50	80	150	220	230	230	450	500	140	393	266	2	18	20
C-9	50	110	170	200	230	420	420	520	750	229	563	396	9	15	24
C-10	50	70	85	100	100	120	120	450	440	92	337	214	4	11	15
C-11	40	60	90	110	90	150	160	230	390	100	260	180	-	-	-
C-12	60	50	100	100	120	130	140	250	410	100	267	184	-	-	-
D-1	100	140	140	250	300	280	260	240	240	210	247	228	8	10	18
D-2	50	180	240	230	300	410	330	220	220	249	257	253	10	10	20
D-3	60	80	100	170	280	330	370	240	300	199	303	251	9	12	21
D-4	10	60	130	240	340	440	450	550	550	239	517	378	-	-	-
D-5	80	110	130	160	180	210	220	280	330	156	277	216	-	-	-
D-6	40	70	100	160	180	170	210	740	750	133	567	350	5	14	19
D-7	90	100	70	50	60	60	60	300	740	70	367	218	-	-	-
D-8	40	70	100	160	290	340	340	370	400	191	370	280	-	-	-
D-9	50	90	130	250	320	350	420	350	350	230	373	302	-	-	-
D-10	40	90	100	80	70	170	270	320	300	117	297	207	2	15	17
D-11	30	80	110	90	80	140	250	340	330	111	307	209	-	-	-
D-12	35	80	120	70	90	160	240	360	310	114	303	208	-	-	-

(Continued)

Table 2 (Continued)

Site Location	Average CI at Depth, in. SFC	1	2	3	4	5	6	9	12	Average CI at Layer, in. 0-6	6-12	0-12	DCPI at Layer, in. 0-6	6-12	0-12
E-1	20	40	50	55	60	70	200	400	750	71	450	260	2	13	15
E-2	40	80	400	750+	750+	750+	750+	750+	750+	503	750+	626+	19	33	52
E-3	50	100	190	290	260	230	260	350	400	197	337	267	6	11	17
E-4	10	40	70	90	100	90	230	470	570	90	423	256	6	17	23
E-5	40	80	250	290	470	750+	750+	750+	750+	376	750+	563+	11	31	42
E-6	30	85	90	110	120	350	450	450	500	176	467	322	3	12	15
E-7	5	40	130	300	380	350	390	600	650	228	547	388	7	16	23
E-8	30	60	60	70	80	90	100	320	240	70	220	145	4	7	11
E-9	30	70	70	90	110	100	130	340	430	86	300	193	4	9	13
E-10	40	80	90	100	110	120	130	460	600	96	397	246	3	9	12
E-11	25	70	80	80	100	90	110	210	380	79	233	156	2	8	10
E-12	30	60	80	90	110	90	120	230	360	83	237	160	2	7	9
F-1	40	45	65	60	70	115	130	350	450	75	310	192	2	8	10
F-2	70	120	120	140	140	350	620	550	550	223	573	398	6	14	20
F-3	50	100	150	240	260	310	400	430	540	216	457	336	7	11	18
F-4	20	80	100	120	130	140	280	450	520	124	417	270	5	12	17
F-5	20	50	70	100	230	310	450	550	500	176	500	338	7	18	2
F-6	30	40	50	65	80	110	190	240	310	81	247	178	3	7	10
F-7	20	50	60	70	70	150	150	320	420	81	297	189	3	8	11
F-8	50	75	110	110	130	115	300	450	620	127	457	292	5	18	23
F-9	50	100	90	110	130	130	250	170	150	123	190	157	4	9	13
F-10	40	110	125	150	170	180	170	450	420	136	347	242	2	10	12
F-11	40	80	100	120	150	170	190	280	380	121	283	202	4	8	12
F-12	40	90	80	130	160	160	180	300	370	120	283	202	4	9	13

(Continued)

Table 2 (Continued)

Site Location	Average CI at Depths, in. SFC	1	2	3	4	5	6	9	12	Average CI at Layer, in. 0-6	6-12	0-12	DCPI at Layer, in. 0-6	6-12	0-12
G-1	65	130	250	400	450	420	470	530	750	312	583	448	-	-	-
G-2	40	140	180	250	270	330	400	500	720	230	540	385	-	-	-
G-3	30	60	120	210	310	400	360	330	300	213	330	272	-	-	-
G-4	60	80	80	130	290	350	350	300	280	191	310	251	5	11	16
G-5	45	90	160	200	190	200	200	250	260	155	237	196	-	-	-
G-6	40	85	120	250	230	220	240	300	250	169	263	216	-	-	-
G-7	20	45	60	90	110	125	150	300	550	86	333	210	-	-	-
G-8	30	50	70	80	110	105	100	230	300	76	210	143	6	13	19
G-9	50	105	130	150	160	150	400	320	270	164	330	247	-	-	-
G-10	40	60	70	85	100	115	130	220	170	86	173	130	-	-	-
G-11	30	40	80	90	110	130	160	170	200	91	177	134	-	-	-
G-12	50	30	80	100	100	120	150	180	210	90	180	135	-	-	-
H-1	20	40	50	80	90	80	100	210	260	66	190	128	7	8	15
H-2	20	30	50	70	70	70	110	200	300	60	203	132	2	9	11
H-3	30	50	80	115	115	250	270	220	260	130	250	190	5	11	16
H-4	30	40	60	80	80	100	110	130	220	71	153	112	3	7	10
H-5	50	110	150	150	150	170	180	320	350	137	283	210	6	12	18
H-6	40	90	130	160	400	500	530	300	380	264	403	334	9	13	22
H-7	20	50	80	120	115	200	250	300	750	119	433	276	3	9	12
H-8	20	60	60	50	50	60	60	150	360	51	190	121	1	8	9
H-9	60	130	140	160	170	170	160	430	430	141	340	241	6	9	15
H-10	60	80	100	100	120	130	160	370	300	107	277	192	4	12	16
H-11	50	70	120	90	100	140	150	190	340	103	227	165	4	11	15
H-12	40	90	110	90	110	120	180	210	360	106	250	178	5	13	18

(Continued)

Table 2 (Concluded)

Site Location	Average CI at Depths, in. SFC	1	2	3	4	5	6	9	12	Average CI at Layer, in. 0-6	6-12	0-12	DCPI at Layer, in. 0-6	6-12	0-12
I-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I-2	40	90	110	120	130	140	190	510	530	117	410	264	-	-	-
I-3	50	70	90	130	200	280	750+	750+	750+	224	750+	487	-	-	-
I-4	50	70	85	100	130	150	240	370	600	118	403	260	-	-	-
I-5	40	70	80	80	90	90	100	350	480	79	310	194	4	19	23
I-6	35	70	80	100	100	120	130	260	440	91	277	184	-	-	-
I-7	35	50	60	60	60	70	110	180	100	64	130	97	-	-	-
I-8	40	60	60	110	140	150	250	370	380	116	333	224	-	-	-
I-9	40	60	70	80	85	130	180	190	350	92	240	166	-	-	-
I-10	50	80	110	150	200	200	310	750+	750+	157	603	380	6	20	26
I-11	35	70	100	130	190	210	280	440	610	145	443	294	-	-	-
I-12	40	70	110	140	170	190	250	510	600	138	453	296	-	-	-
J-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J-2	40	100	150	180	250	350	380	470	450	207	433	320	9	23	32
J-3	50	50	50	70	70	90	180	570	570	80	440	260	4	23	27
J-4	30	40	60	80	80	100	140	180	150	76	157	116	3	6	9
J-5	60	50	50	60	90	110	120	120	150	77	130	104	4	5	9
J-6	40	80	150	170	180	220	380	320	150	174	283	228	6	20	26
J-7	40	70	80	160	240	290	300	330	550	169	393	281	7	21	28
J-8	50	75	80	90	135	180	190	300	500	114	330	222	5	14	19
J-9	50	50	50	50	50	80	140	150	130	67	140	104	3	7	10
J-10	30	70	100	150	210	220	220	300	200	142	240	191	8	10	18
J-11	40	60	110	140	200	210	260	320	340	146	307	226	9	16	25
J-12	40	50	110	160	190	210	250	340	300	144	297	220	8	15	23

(Sheet 5 of 5)

Table 3

Soil Strength Data at Mine Impact Locations, I Field, APG, Maryland

Mine		Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
No.	Type	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
1	AF	33	137	173	207	233	260	297	327	510	191	378	284	7	12	19
2	110*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	S	30	70	190	353	417	410	423	597	677	270	566	418	10	16	26
4	AF	53	93	147	163	250	377	457	630	630	220	572	396	10	25	35
5	110	100	160	257	397	457	460	567	623	572	343	587	465	13	17	30
6	S	40	57	73	87	100	118	197	343	433	96	324	210	3	15	18
7	AF	22	52	95	150	183	193	223	407	717	131	449	290	9	21	30
8	110*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	S	70	113	123	143	173	217	413	583	550	179	515	347	5	24	29
10	AF	18	60	77	90	168	243	327	487	400	140	405	272	4	12	16
11	110	23	28	38	33	27	32	62	113	750	35	308	172	2	18	20
12	S	163	213	260	270	280	277	297	330	373	251	333	292	10	14	24
13	AF	60	147	190	243	363	433	440	503	640	268	528	398	9	25	34
14	110	32	40	45	55	60	67	77	153	337	54	189	122	2	6	8
15	S*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	AF	37	65	72	95	103	98	105	557	750	82	471	276	7	31	38
17	AF	32	48	53	50	47	92	167	187	247	70	200	135	3	9	12
18	AF	47	56	45	53	107	113	107	207	360	75	225	150	2	6	8
19	AF	23	63	147	153	270	357	407	750	607	203	588	396	9	20	29
20	AF	77	130	150	170	173	167	183	627	647	150	486	318	6	24	30
21	110	85	100	107	110	150	337	367	453	387	179	402	291	6	10	16
22	110	63	137	166	187	303	533	750	750	750	306	750	528	18	18	36
23	110	40	80	123	172	187	320	417	560	683	191	553	372	9	13	22
24	110*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	110	57	93	110	110	127	160	190	560	740	121	497	309	3	19	22

(Continued)

* Mine lost.

Table 3 (Continued)

Mine		Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
No.	Type	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
26	S	37	40	45	43	50	67	107	187	260	56	185	120	2	8	10
27	S	67	100	130	133	173	330	373	513	443	187	443	315	4	11	15
28	S	30	45	53	77	107	130	167	193	213	87	191	139	2	6	8
29	S	57	100	125	170	223	297	307	367	357	183	344	263	8	10	18
30	S	33	63	80	123	197	233	307	273	383	148	321	234	2	6	8
31	AF	123	280	317	370	410	477	460	567	703	348	577	462	11	20	31
32	AF	73	190	203	423	667	750	750	750	750	436	750	593	11	14	25
33	AF	25	70	97	103	107	140	215	667	750	108	544	326	5	12	17
34	AF	70	90	105	102	105	113	143	153	330	104	209	156	2	8	10
35	AF	37	70	100	133	140	137	220	393	580	120	398	259	3	11	14
36	110	37	90	107	120	117	105	110	103	330	98	181	140	3	4	7
37	110*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	110**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	110	77	137	183	270	293	450	507	463	480	274	483	379	9	14	23
40	110	103	187	260	237	240	330	350	493	367	244	403	324	11	13	24
41	S	73	143	207	283	343	430	467	400	387	278	418	348	11	15	26
42	S	47	93	117	127	117	127	133	120	130	109	128	118	4	3	7
43	S	27	53	65	93	122	127	157	260	333	92	250	171	5	10	15
44	S	70	120	173	210	317	380	443	560	573	245	525	385	7	10	17
45	S	33	103	227	380	383	400	390	393	383	274	389	331	11	8	19
46	AF	73	193	213	213	250	310	433	317	250	241	333	287	11	11	22
47	AF	77	137	277	583	675	750	750	750	750	464	750	607	19	29	48
48	AF	63	157	160	237	317	427	443	323	340	258	369	313	9	16	25
49	AF	27	128	100	160	200	227	227	177	513	153	306	229	6	7	13
50	AF	83	267	343	317	450	617	550	433	327	375	436	406	18	17	35

(Continued)

* Mine lost.
** Mine hit pavement behind shop.

Table 3 (Continued)

Mine		Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
No.	Type	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
51	110	20	73	157	267	313	393	473	528	417	242	473	357	8	20	28
52	110	73	137	157	187	213	280	490	650	647	220	596	408	11	28	39
53	110	63	120	127	90	93	127	337	570	700	137	536	336	5	22	27
54	110	15	47	63	83	300	300	397	420	547	172	455	313	12	15	27
55	110	27	67	130	190	213	233	273	390	443	162	369	265	8	12	20
56	S	37	53	77	83	163	180	160	233	317	108	237	172	6	8	14
57	S	37	140	133	147	157	237	290	333	420	163	348	255	8	10	18
58	S	47	123	223	313	370	557	620	707	670	322	666	494	9	18	27
59	S	43	113	123	163	213	253	273	323	623	169	406	288	5	15	20
60	S	100	137	150	177	203	257	380	427	343	201	383	292	8	16	24
61	AF	87	113	130	117	133	113	107	130	73	114	103	109	5	4	9
62	AF	40	103	133	150	150	150	240	450	667	138	452	295	7	18	25
63	AF	30	40	50	77	90	113	333	490	510	105	444	275	2	15	17
64	AF	97	253	340	350	370	337	390	460	500	305	450	378	17	32	49
65	AF	117	220	223	223	257	367	493	750	750	271	664	468	5	26	31
66	110	43	80	113	137	155	173	587	370	456	184	471	328	3	14	17
67	110	76	170	210	210	235	223	240	750	750	195	580	388	7	20	27
68	110*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69	110	23	56	93	143	111	130	163	290	336	103	263	183	3	15	18
70	110	46	100	133	160	186	200	213	186	266	148	222	185	7	8	15
71	S	50	103	130	166	173	183	266	166	473	153	302	227	4	11	15
72	S	53	96	46	43	160	233	273	430	546	129	416	273	9	19	28
73	S	80	193	193	203	196	220	276	323	406	194	335	264	13	12	25
74	S	50	133	213	266	283	300	356	410	436	229	301	315	8	12	20
75	S	73	120	166	213	223	236	306	323	346	191	325	248	9	10	19

(Continued)

* Mine lost.

Table 3 (Concluded)

Mine		Average CI at Depth, in.									Average CI at Layer, in.			DCPI at Layer, in.		
No.	Type	SFC	1	2	3	4	5	6	9	12	0-6	6-12	0-12	0-6	6-12	0-12
76	S	63	133	200	276	310	320	346	526	580	235	484	360	7	11	18
77	S	70	176	250	303	313	333	413	396	530	265	446	356	9	10	19
78	S	73	26	356	383	450	560	560	623	750	344	644	494	12	26	38
79	S	153	376	633	750	750	750	750	750	750	594	750	672	26	21	47
80	S	33	66	110	176	273	313	373	300	713	192	462	327	13	26	39
81	110	140	110	123	146	130	116	123	310	506	127	313	220	3	10	13
82	110	110	206	230	246	230	230	360	366	276	230	334	282	10	8	18
83	110	40	90	120	163	190	206	226	423	516	148	388	268	5	15	20
84	110	43	60	93	126	213	303	375	590	750	173	571	372	7	22	29
85	110	66	90	120	196	240	260	286	516	650	180	484	332	8	11	19
86	AF	43	133	173	186	210	250	326	530	650	189	502	346	10	25	35
87	AF	40	40	43	70	58	43	40	30	131	48	67	58	2	1	3
88	AF*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Mine lost.

(Sheet 4 of 4)

Table 4

Mine Data at I Field, APG, Maryland

Mine No.	Mine Type	Site*	Horizontal Displacement After Impact in.	Penetration in. Initial	Penetration in. Final	Impact Attitude**	Impact Angle deg	Final Attitude**	At-Rest Angle deg	Depth of Overburden in.	Location Relative to Site Position
1	AF	E-3	0	3	1.5	A	43	A	27.5	0	100 ft N, 40 ft W
2†	110	E-3	-	-	-	-	-	-	-	-	-
3	S	D-5	36	1.5	0	B	86	B	90	0	90 ft E
4	AF	D-5	15	2.5	0	E	46	A	NM	0	-
5	110	A-9	56	2	0	A	38	C	7.5	0	40 ft N, 700 ft W
6	S	F-10	0	3.5	3.5	A	90	A	29	0	25 ft N
7	AF	E-7	36	2.5	0	D	68	A	5	0	60 ft N, 60 ft W
8†	110	E-7	-	-	-	-	-	-	-	-	-
9	S	H-4	16	2.5	0	C	UK	A	UK	0	70 ft N, 80 ft E
10	AF	D-6	0	5	5	A	69	C	23	0	100 ft N, 100 ft W
11	110	A-9	0	4	4	A	41.5	D	32	0	60 ft S, 480 ft W
12	S	A-1	34	2.5	0	B	52	A	1	0	300 ft S
13	AF	I-6	36	3.25	0	C	48	A	2	0	80 ft N, 40 ft E
14	110	H-7	0	4	4	E	50	C	22.5	0	20 ft N, 20 ft E
15†	S	H-7	-	-	-	-	-	-	-	-	-
16	AF	G-6	0	4.25	4.25	A	46.5	A	12	0	40 ft S, 100 ft W
17	AF	H-5	0	4	4	C	44	A	8.5	0	40 ft N, 60 ft W
18	AF	G-7	0	9.5	9.5	A	50	A	37	2.5	40 ft E
19	AF	E-6	0	2.75	2	A	47	A	8	0	80 ft N, 20 ft E
20	AF	E-8	36	3.5	0	A	33	A	10	0	100 ft N, 100 ft E

(Continued)

NOTE: UK = unknown, NM = not measured.
* Alphanumeric system used to identify grid intersections shown in Figure 3.
** See Figure 4 for attitude definition.
† Lost.

Table 4 (Continued)

Mine No.	Mine Type	Site	Horizontal Displacement After Impact in.	Penetration in. Initial	Penetration in. Final	Impact Attitude	Impact Angle deg	Final Attitude	At-Rest Angle deg	Depth of Overburden in.	Location Relative to Site Position
21	110	D-10	9	3	0	A	87	B	90	0	100 ft N, 100 ft E
22	110	G-11	40	2.5	0	A	32	B	0	0	40 ft E
23	110	F-3	7	3	0	NM	20	A	4.5	0	60 ft S, 40 ft E
24†	110	F-3	-	-	-	-	-	-	-	-	-
25	110	G-11	115	3.5	0	E	42	B	0	0	80 ft N, 100 ft W
26	S	K-5	0	5.5	5.5	C	51	C	25	0	30 ft N, 90 ft E
27	S	E-2	0	2.75	2.75	C	24	C	12.4	0	30 ft S, 20 ft W
28	S	I-3	37	3	0	B	86	B	NM	0	80 ft N, 80 ft W
29	S	A-2	0	3	3	C	NM	C	NM	0	40 ft N
30	S	G-3	12	0	0	A	NM	A	NM	0	80 ft N
31	AF	C-3	0	7	7	E	76	E	76	0	60 ft N, 80 ft W
32	AF	A-2	0	3.75	3.75	C	38	C	38	0	20 ft S, 60 ft E
33	AF	B-4	0	6.75	6.75	B	NM	B	20	1.75	40 ft N
34	AF	D-6	0	6.75	6.75	A	64	A	21	0	80 ft N
35	AF	B-6	0	3.5	3.5	A	51	A	11.5	0	100 ft N, 20 ft E
36	110	A-1	0	3.75	3.75	A	0	A	9.5	0	500 ft S
37†	110	A-1	-	-	-	-	-	-	-	-	-
38	110	A-1	324	0	0	A	UK	B	90	0	Hit asphalt
39	110	A-12	0	2.25	2.25	C	24	C	24	0	40 ft N, 40 ft E
40	110	C-10	0	1.75	1.75	A	15	A	15	0	100 ft N, 20 ft W

(Continued)

† Lost.

Table 4 (Continued)

Mine No.	Mine Type	Site	Horizontal Displacement After Impact in.	Penetration in. Initial	Penetration in. Final	Impact Attitude	Impact Angle deg	Final Attitude	At-Rest Angle deg	Depth of Overburden in.	Location Relative to Site Position
41	S	I-1	43	3	0	C	44	A	5	0	40 ft S, 40 ft E
42	S	H-3	0	2.75	2.25	C	34.5	C	34.5	0	80 ft W
43	S	H-5	30	1.25	0	A	45	A	4	0	100 ft N, 40 ft W
44	S	D-10	19	2.75	0	C	29	A	21.5	0	40 ft N, 40 ft W
45	S	E-3	23	2.25	0	A	36	A	1	0	60 ft N, 60 ft E
46	AF	C-11	0	4	4	E	61	E	61	0	20 ft S, 60 ft W
47	AF	D-4	18	3.25	0	B	45	A	8	0	40 ft S, 80 ft W
48	AF	F-4	13	4.5	0	A	90	A	9	0	60 ft S, 60 ft E
49	AF	E-3	0	2.5	2.5	A	UK	A	5	0	20 ft N, 80 ft E
50	AF	B-3	9	2.25	0	A	0	A	5	0	60 ft E
51	110	B-7	78	1.5	0	B	NM	A	5	0	20 ft S, 60 ft E
52	110	D-10	38	1.75	0	A	UK	A	21	0	20 ft N, 20 ft W
53	110	D-12	0	4	4	C	46	C	46	0	60 ft S, 60 ft E
54	110	C-6	0	2.25	2.25	A	32	A	6.5	0	100 ft N, 60 ft E
55	110	D-5	142	2.25	0	A	37	B	7	0	40 ft N, 20 ft W
56	S	H-4	34	2.5	0	C	31	A	7	0	60 ft S, 40 ft W
57	S	G-3	0	2	2	A	90	A	10	0	60 ft E
58	S	E-1	183	4	0	C	34	B	0	0	100 ft N, 20 ft E
59	S	F-1	0	3	3	C	38	A	18	0	200 ft S, 20 ft E
60	S	F-4	8	2.5	0	A	51	A	9	0	100 ft S, 100 ft E

(Continued)

Table 4 (Continued)

Mine		Site	Horizontal Displacement After Impact in.	Penetration in.		Impact Attitude	Impact Angle deg	Final Attitude	At-Rest Angle deg	Depth of Overburden in.	Location Relative to Site Position
No.	Type			Initial	Final						
61	AF	A-8	0	7.75	7.75	C	43	C	43	5.0	40 ft N, 40 ft E
62	AF	F-5	0	5.5	5.5	D	49.5	D	49.5	0	20 ft S, 100 ft E
63	AF	B-6	8	5	0	B	52.5	A	23	0	20 ft N, 80 ft E
64	AF	F-8	Old Rut	2	0	A	0	A	13	0	100 ft N, 40 ft E
65	AF	E-7	0	3.75	3.75	E	42	E	42	0	20 ft N, 20 ft W
66	110	A-7	0	2.5	2.5	A	79	A	11	0	200 ft W
67	110	J-6	25	1.75	1.75	A	38.5	B	83	0	40 ft S
68†	110	J-6	-	-	-	-	-	-	-	-	-
69	110	G-10	4	3	3	B	47	B	75	0	80 ft N, 20 ft E
70	110	G-7	8	2	1	E	34	C	58	0	40 ft S, 40 ft E
71	S	G-5	0	3.5	3.5	C	40	C	74	0	40 ft N
72	S	H-1	6	2	0	A	56.5	A	0	0	120 ft S, 80 ft E
73	S	F-5	34	2.25	0	C	25.5	A	13.5	0	40 ft S, 20 ft E
74	S	E-3	4	1.25	0	A	58	A	15	0	20 ft N, 40 ft E
75	S	G-1	0	2.75	2.75	C	19	C	25	0	100 ft N, 20 ft E
76	S	G-2	12	2.25	0	C	35	C	12	0	40 ft S, 20 ft W
77	S	D-4	9	3	0	C	34	A	9	0	60 ft S, 20 ft W
78	S	B-4	73	2	0	A	NM	A	8	0	40 ft S, 60 ft W
79	S	B-1	140	1.75	0	C	NM	A	90	0	100 ft N, 40 ft E
80	S	F-6	0	2.5	2.5	C	45	C	45	0	40 ft N, 80 ft W

(Continued)

† Lost.

(Sheet 4 of 5)

Table 4 (Concluded)

Mine		Site	Horizontal Displacement After Impact in.	Penetration in.		Impact Attitude	Impact Angle deg	Final Attitude	At-Rest Angle deg	Overburden in.	Location Relative to Site Position
No.	Type			Initial	Final						
81	110	I-10	81	2.25	0	A	35	A	14	0	60 ft W
82	110	G-10	180	2	0	A	NM	A	NM	0	40 ft N, 80 ft E
83	110	B-7	0	2.5	2.5	A	59	A	31	0	40 ft S, 80 ft W
84	110	I-7	9	2.75	0	A	41	C	37	0	20 ft S, 20 ft W
85	110	D-7	44	3.5	0	C	31	A	0	0	80 ft E
86	AF	A-6	0	7.5	7.5	B	67	D	67	0	40 ft S, 40 ft W
87	AF	A-8	0	9	9	B	65	B	25	UK	40 ft E
88†	AF	A-8	-	-	-	-	-	-	-	-	-

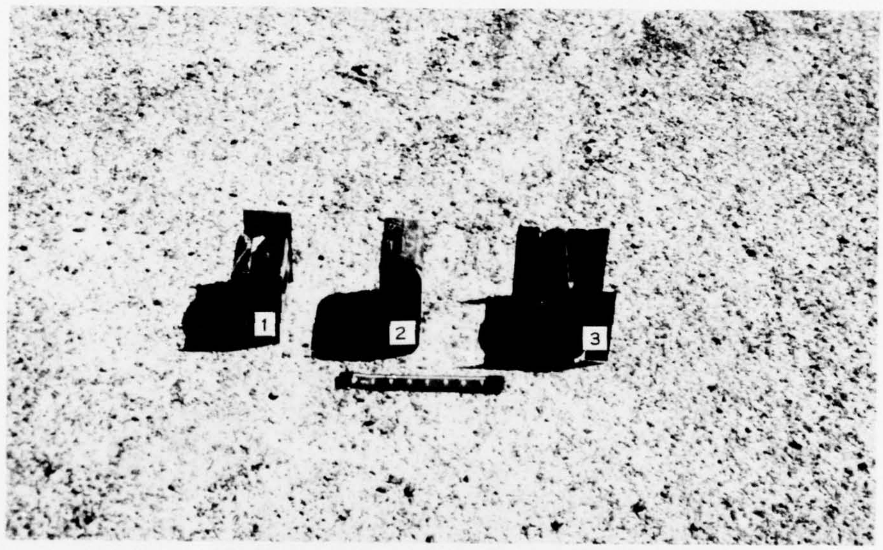
† Lost.

(Sheet 5 of 5)

Table 5

CI Trafficability Data (from Reference 4)

Minimum CI Required for 50 Passes of the 6- to 12-in. Layer	Standard Military Vehicles
20-29	M29 Weasel, M76 Otter, and Canadian Snowmobile are the only known military vehicles in this category
30-49	Engineer and high-speed tractors with comparatively wide tracks and low contact pressures
50-59	Tractors with average contact pressures, tanks with comparatively low contact pressures, and some trailed vehicles with very low contact pressures
60-69	Most medium tanks, tractors with high contact pressures, and all-wheel-drive trucks and trailed vehicles with low contact pressures
70-79	Most all-wheel-drive trucks, a great number of trailed vehicles, and heavy tanks
80-99	A great number of all-wheel-drive and rear-wheel-drive trucks, and trailed vehicles intended primarily for highway use
100 or greater	Rear-wheel-drive vehicles and others that generally are not expected to operate off roads, especially in wet soils



LEGEND

1 S-SHAPED
2 AIR FORCE
3 110

Figure 1. Mines tested

a. Looking northeast

b. Looking east

c. Looking southeast

d. Looking west

Figure 2. Overviews of I Field (17 April 1977)

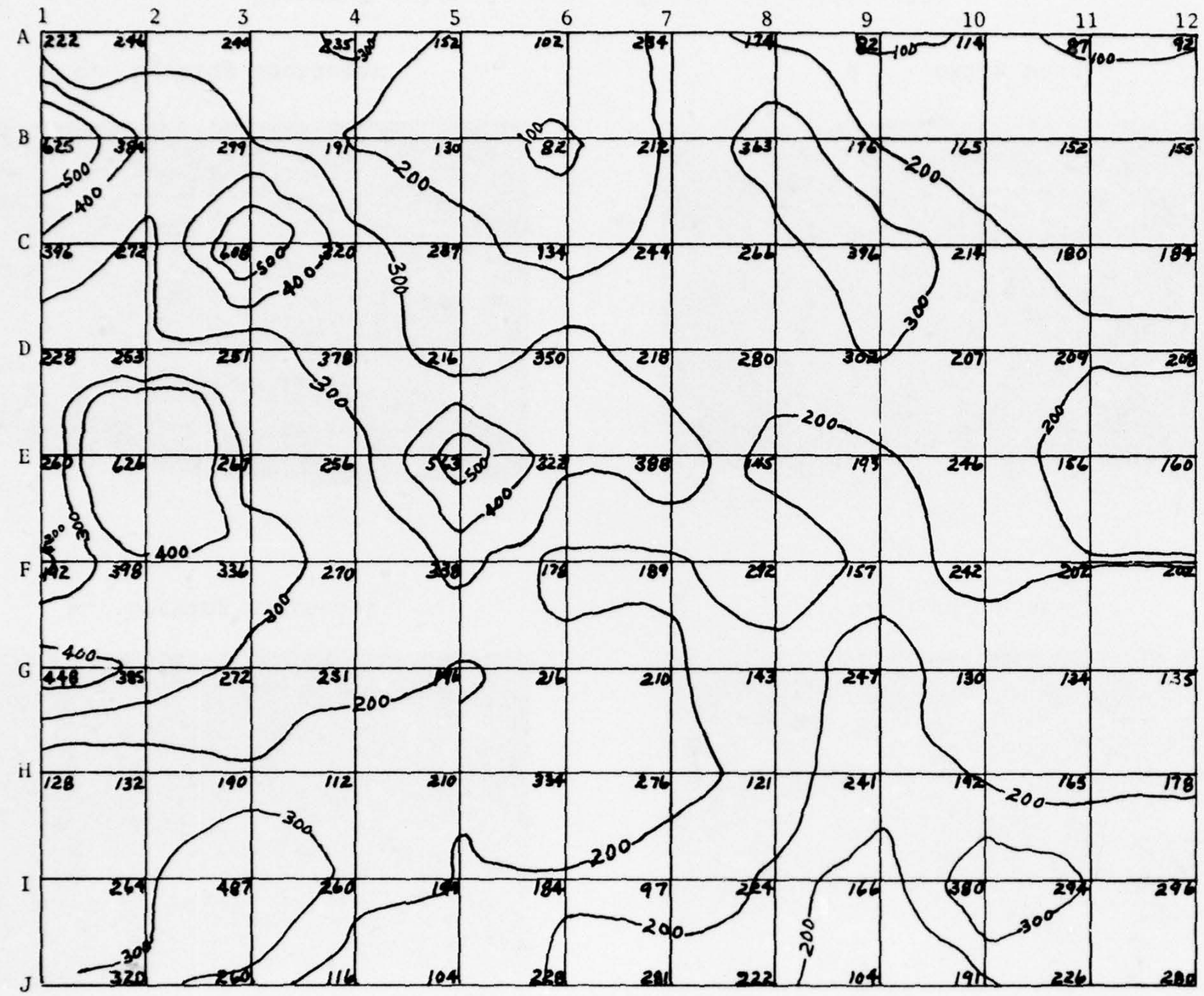
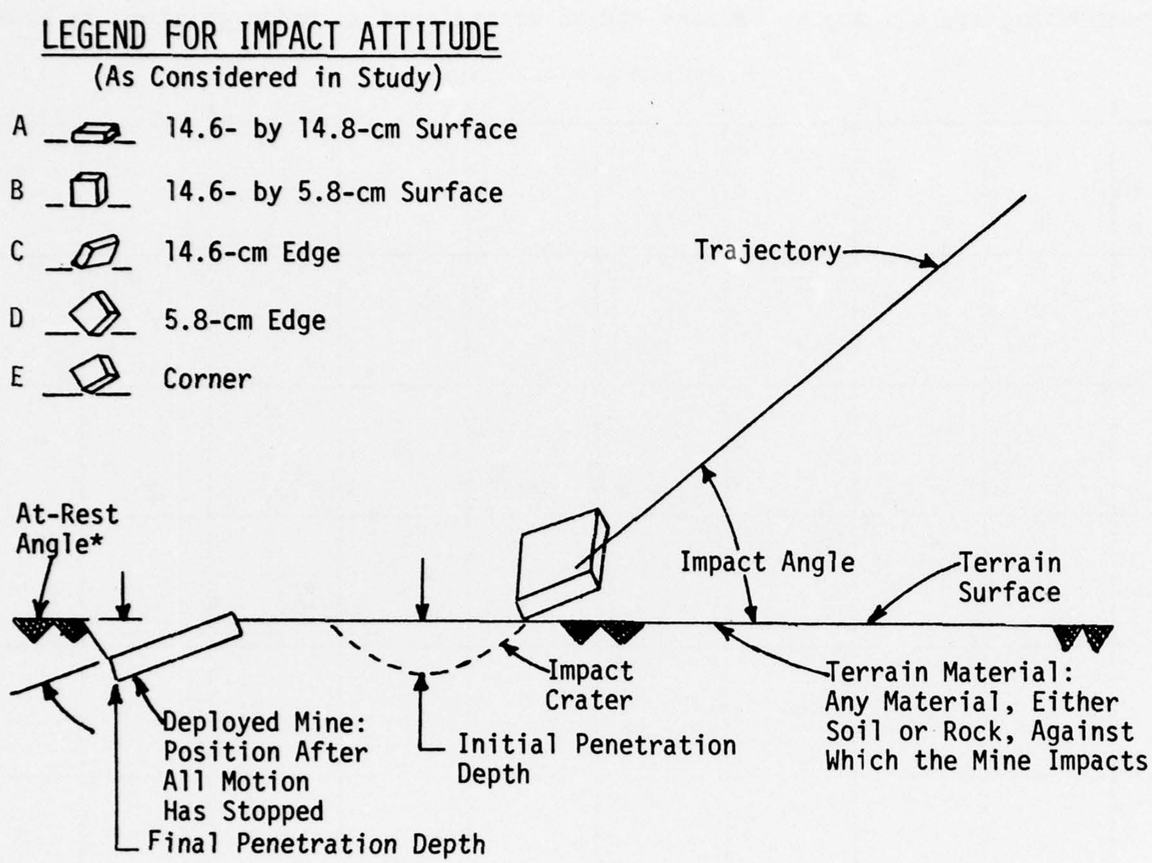


Figure 3. Distribution of average 0- to 12-in. CI



* At-rest angle is the angle formed between a 14.6- by 14.6-cm face and the surface. If the mine is lying flat on the surface, the at-rest attitude is 0 degree; if standing on edge, the at-rest attitude is 90 degrees.

Figure 4. Mine impact definitions

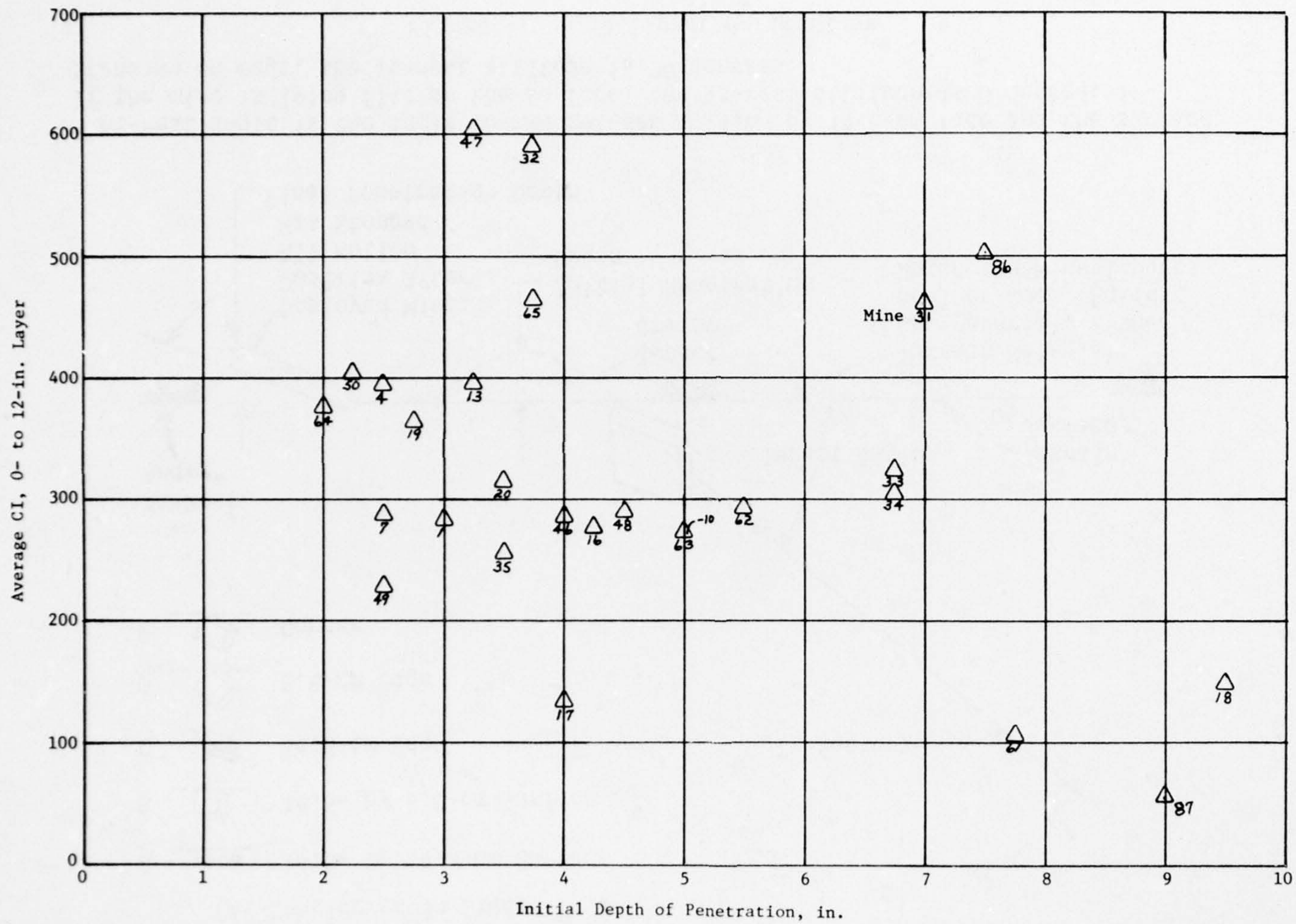


Figure 5. Initial depth of penetration versus average CI for the Air Force mine

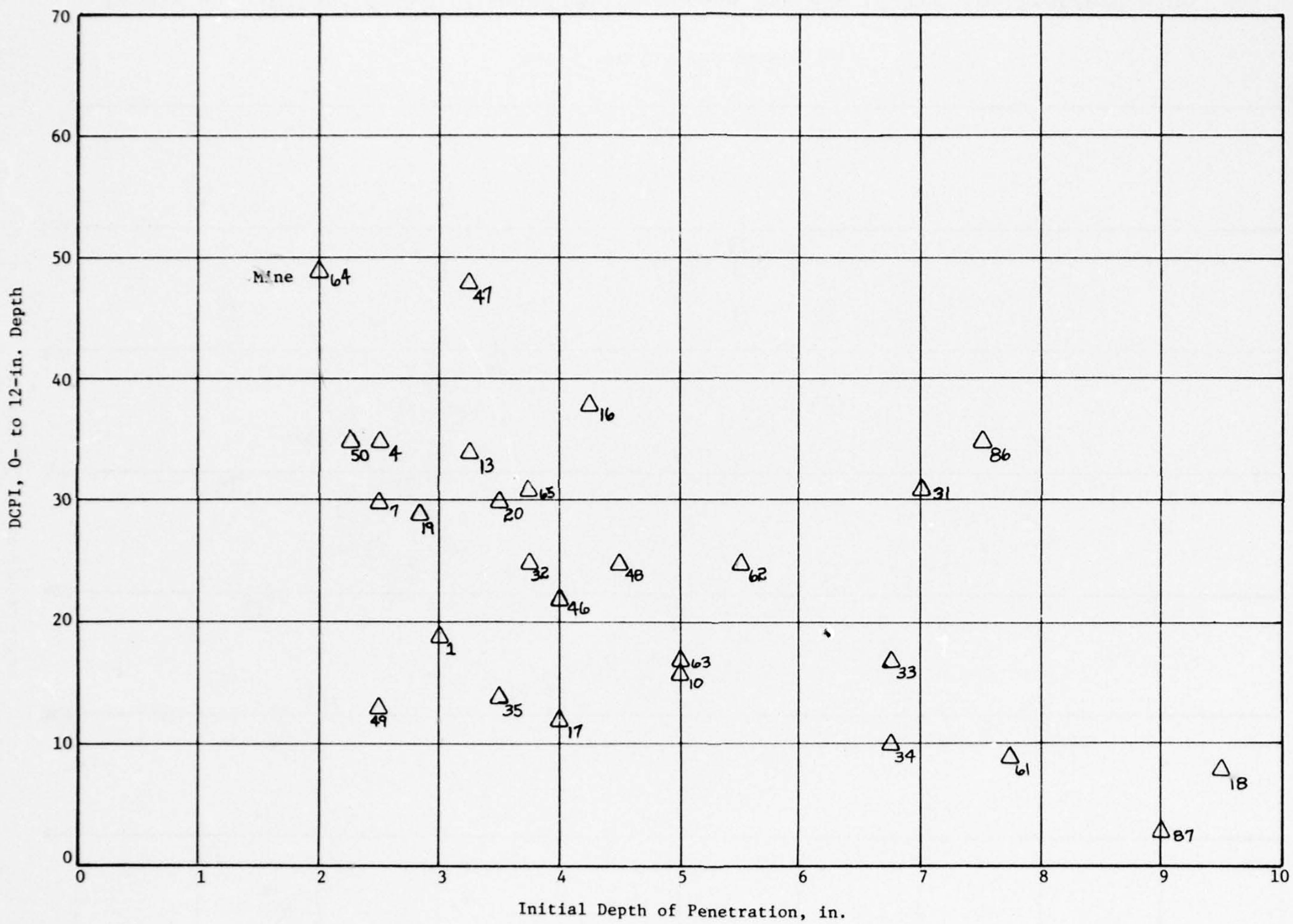


Figure 6. Initial depth of penetration versus DCPI for the Air Force mine

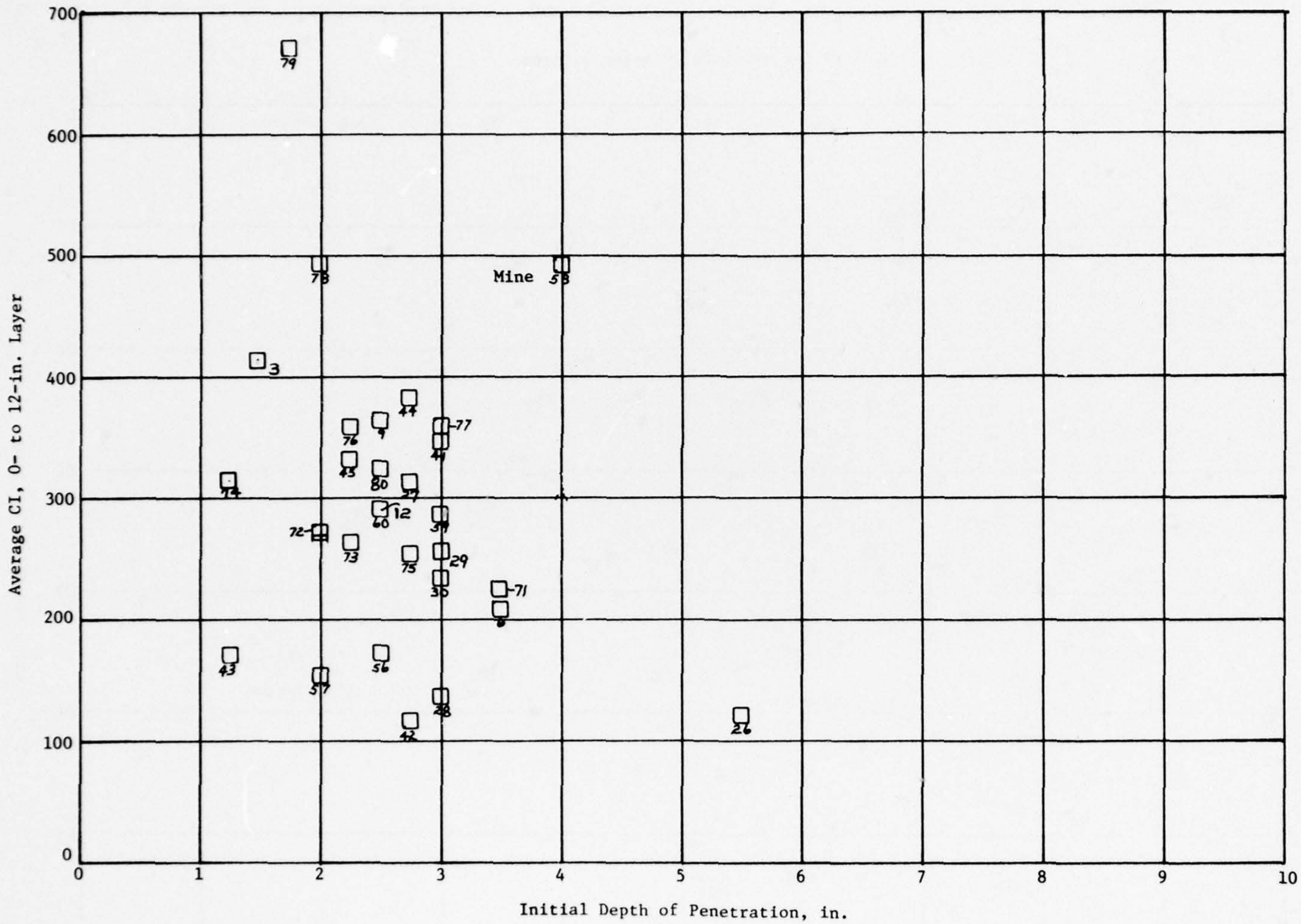


Figure 7. Initial depth of penetration versus average CI for the S-shaped mine

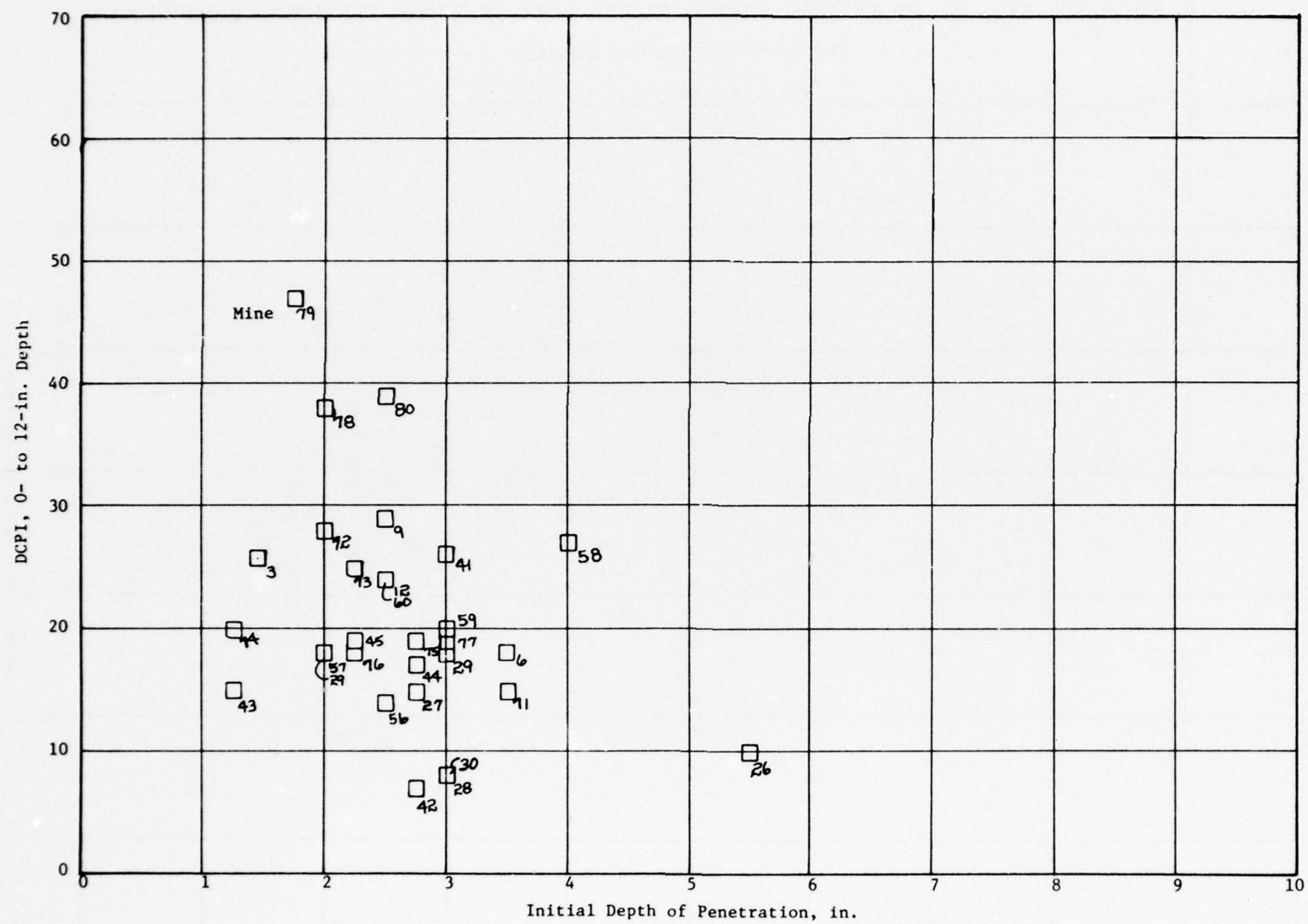


Figure 8. Initial depth of penetration versus DCPI for the S-shaped mine

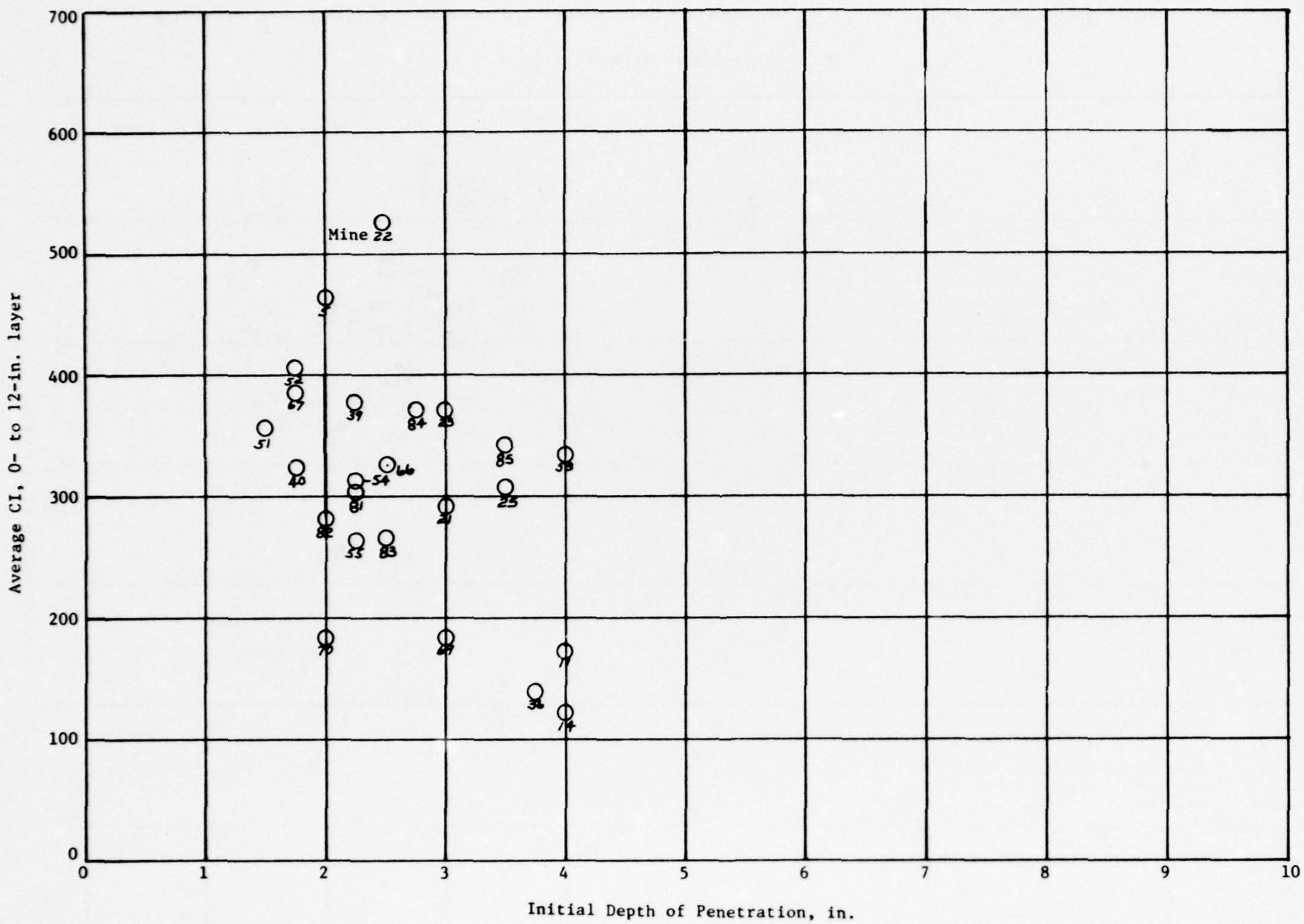


Figure 9. Initial depth of penetration versus average CI for the 110 mine

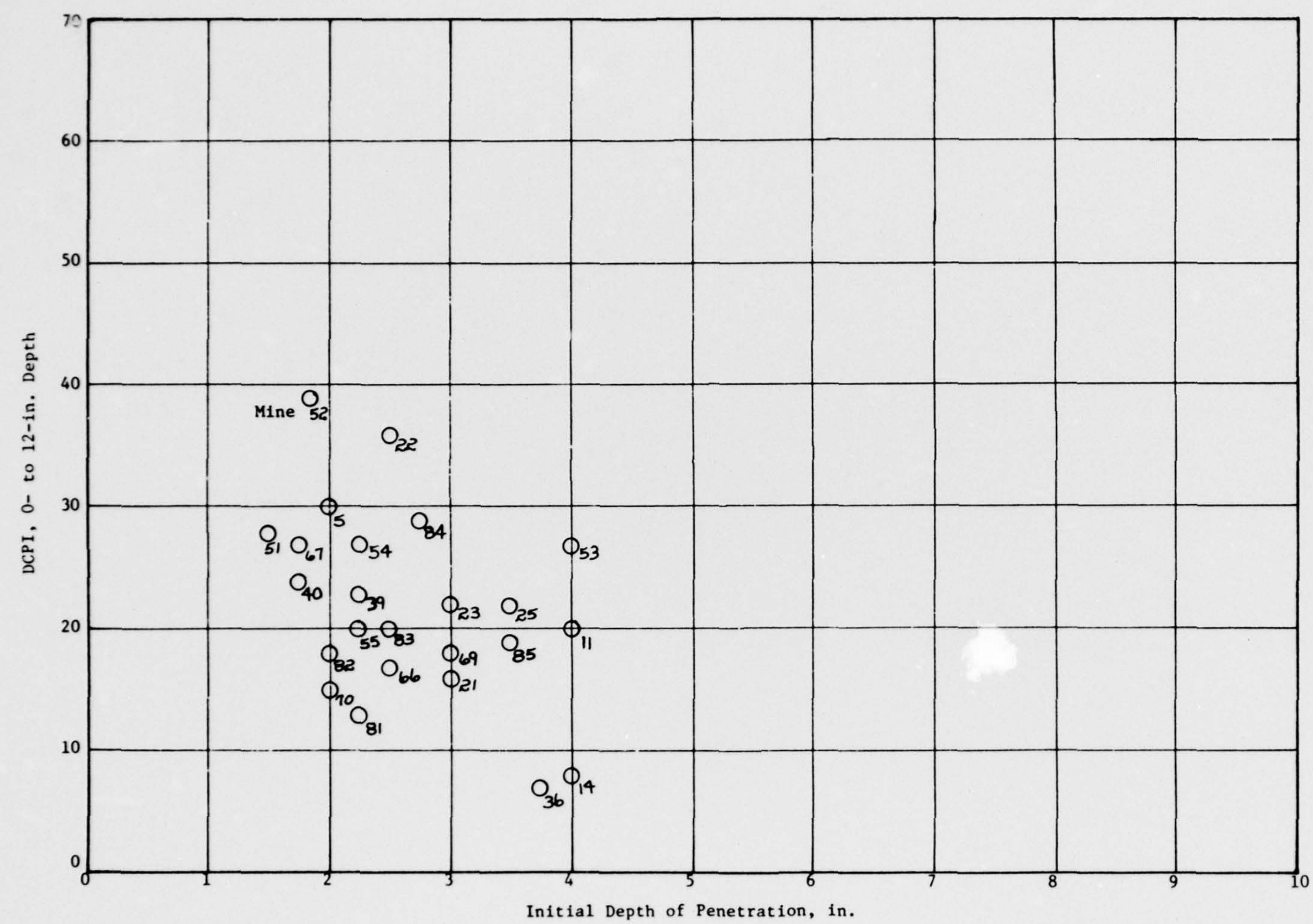


Figure 10. Initial depth of penetration versus DCPI for the 110 mine

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Green, Charles E
  Terrain characteristics at Gator Mine impact and penetration test sites, Aberdeen Proving Ground, Maryland / by Charles E. Green. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.
  14, [27] p. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; M-77-13)
  Prepared for Picatinny Arsenal, Dover, New Jersey.
  References: p. 14.

1. Impact tests. 2. Mines (Ordnance). 3. Off-road mobility. 4. Penetration tests. 5. Soil penetration tests. 6. Soil strength. 7. Terrain. I. United States. Picatinny Arsenal, Dover, N. J. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; M-77-13.
TA7.W34m no.M-77-13